AD-A243 241

FIRE RETARDANT PERFORMANCE OF SOME INTERIOR SHIPBOARD PAINT SCHEMES

(2)

AR-006-821

L.V. WAKE

MRL-TR-91-31

MATERIALS RESEARCH LABORATORY

DSTO

Fire Retardant Performance of Some Interior Shipboard Paint Schemes

L.V. Wake

MRL Technical Report
MRL-TR-91-31

Abstract

The fire retardant performance of alternative paints to the alkyd paint system presently protecting the interior areas of Royal Australian Navy (RAN) ships has been evaluated. Topcoats investigated were: (i) a polyvinylidene chloride (PVDC) latex paint; (ii) an acrylic latex paint; (iii) an epoxy polyester paint, and (iv) the RAN alkyd paint. The paints were examined in a number of primer/topcoat systems by combustion under limiting oxygen index (LOI), radiant heat exposure, direct flame exposure and reverse panel heating. Some rating variation between procedures was observed although the latex based PVDC topcoat had the highest rating by all test methods. The variability was exemplified by the present RAN fire retardant alkyd paint which successfully passed the reverse panel heating test, had a self-extinguishing LOI of 28.9%, yet had a high flame spread by radiant heating and direct flame exposure. A paint scheme comprising an epoxy polyamide primer and a PVDC topcoat exhibited excellent fire retardant and maintenance properties and should be considered by RAN for a trial to determine in-Service shipboard performance.

MATERIALS RESEARCH LABORATORY

Published by

DSTO Materials Research Laboratory
Cordite Avenue, Maribyrnong
Victoria, 3032 Australia

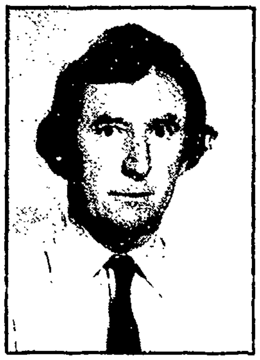
Telephone: (03) 319 3887
Fax: (03) 318 4536

AR No. 006-821

APPROVED FOR PUBLIC RELEASE

Author

L.V. Wake



Lindsay Vernon Wake was awarded a Department of Supply scholarship to complete a PhD at the University of NSW in 1969. He joined MRL in 1972 and was briefly associated with the Textiles Group and later the Marine Environment Group of MRL. Since 1981, Dr Wake has been located in Paint Technology where he has formed a close working association with the RAAF. He is currently investigating the synthesis and performance of fire retardant paints, high temperature resistant coatings, NIR camouflage paints and other coating materials of Defence interest.

Contents

1. INTRODUCTION **7**

2. MATERIALS AND METHODS **8**
2.1 *Paints* **8**
2.1.1 *Topcoats* **8**
2.1.2 *Primers* **9**
2.1.3 *Paint Schemes* **10**
2.2 *Painting Procedure* **10**
2.3 *Resistance of Paints to Combustion* **10**
2.3.1 *Evaluation of Fire Retardancy by Reverse Panel Heating* **10**
2.3.2 *Limiting Oxygen Index (LOI)* **11**
2.3.3 *Assessment of Early Fire Hazard Properties of Materials* **11**
2.3.4 *Direct Flame Impingement (2-Foot Tunnel Test)* **12**
2.4 *Scrub Resistance* **12**
2.5 *Salt Spray Resistance* **13**
2.6 *Washability* **13**

3. RESULTS **13**
3.1 *Resistance of Paints to Combustion* **13**
3.1.1 *Evaluation of Fire Retardancy by Reverse Panel Heating* **14**
3.1.2 *Limiting Oxygen Indices* **14**
3.1.3 *Early Fire Hazard Properties* **15**
3.1.4 *2-Foot Tunnel Test* **16**
3.2 *Application Properties* **16**
3.3 *Gloss* **17**
3.4 *Scrub Resistance* **17**
3.4.1 *Alkyd System* **18**
3.4.2 *Acrylic Topcoat* **18**
3.4.3 *PVDC Topcoat* **18**
3.5 *Salt Spray Resistance* **18**
3.6 *Washability* **18**

4. DISCUSSION **19**

5. CONCLUSIONS **21**

6. REFERENCES **22**

APPENDIX 1 — *Reverse Panel Heating Performance of Paint Systems (AS K179–1969)* **24**

Fire Retardant Performance of Some Interior Shipboard Paint Schemes

1. Introduction

There is considerable variation in the fire retardant paint systems presently employed by allied Navies for interior ship protection. In the absence of any agreed fire examination procedure, the paint system employed by each Navy tends to reflect the suitability of the system to the fire testing procedure. In an effort to establish the merits of the various evaluation approaches, a number of paint schemes being used or considered for interior use in naval vessels were examined by four inherently different methods, namely: (i) a radiant heat procedure (Early Fire Hazard Guidance Test, AS 1530-3) [1], (ii) direct flame impingement (Monsanto Two-foot Tunnel Test, ASTM D3806) [2], (ii) reverse panel heating (AS 179-1969) [3] and (iv) combustion under a limiting oxygen atmosphere (Limiting Oxygen Index Test, ASTM D2863 and AS 2122.2) [4]. The aim of this investigation was to resolve possible bias between the different procedures. It was also believed that a better measure of relative performance of the paint schemes would be revealed by evaluating the coatings against each of the procedures.

The paint scheme used by the RAN for shipboard interiors consists of a solvent-borne alkyd primer and an alkyd topcoat enamel. The topcoat has a degree of fire retardancy by virtue of its high pigment loading and by the addition of a small amount of chlorinated hydrocarbon. This paint is required to pass a fire resistance test which involves heating a steel panel on the reverse side to the paint [3]. The development of this method arose in World War II following the propagation of shipboard fires from one sealed compartment to another by heat transmitted through bulkheads [5].

Recent experiences from both laboratory examination [6] and naval operations [7] have shown that the fire retardant properties of alkyd paint schemes have shortcomings which make their replacement desirable. The elimination of solvents from RAN ships is also necessary on health and safety grounds. In view of these aspects, two water based topcoats were examined, namely a polyvinylidene chloride (PVDC) based resin formulation known to

have a high limiting oxygen index (LOI), and a gloss acrylic latex paint. The US Navy [7] employs PVDC paint coatings because of their high level of fire retardance while acrylic paints are under consideration by New Zealand naval personnel [8] for HMNZ ships. Two solvent based coatings, the epoxy polyester paint presently used in RAN submarines and the alkyd paint presently used on the interior areas of RAN ships were also examined. These paints were applied over a number of different solvent and water based primers to evaluate the performance of the overall systems.

2. *Materials and Methods*

2.1 *Paints*

The topcoats and primers which were examined are listed in Table 1 (Section 7). All are being used or considered for use in naval ships. A number of experimental paints were formulated by the addition of hydrated alumina to the epoxy polyester topcoat and epoxy polyamide primer and are shown in Table 2.

2.1.1 *Topcoats*

The four topcoats were selected for the following reasons:

(i) **Alkyd topcoat** (Table 1; No. T1). The alkyd semigloss topcoat is presently used by RAN on the interior areas of ships and was examined to provide a reference measure.

(ii) **Acrylic gloss latex paint** (Table 1; No. T2). The acrylic gloss latex paint is being examined by New Zealand naval personnel as a readily available replacement for solvent-borne alkyd paints.

(iii) **PVDC latex paint** (Table 1; No. T3). The experimental PVDC topcoat is based on a commercially available poly(vinylidene chloride-vinyl chloride) resin. Paints based on PVDC resins are being used by the US Navy and exhibit very good fire retardant properties [6].

(iv) **Epoxy polyester paint** (Table 1; No. T4). Gloss epoxy polyester paints are used on RAN submarine bulkheads and overheads, and occasionally on surface ships. Paints based on epoxy polyester resins have better non-yellowing properties than the alkyd paints and excellent gloss characteristics. They are approved under the GPC-E-82 specification for use on submarines.

Table 1: Paint Systems for Evaluation

No.	Topcoat	No.	Primer
T1	Fire retardant semi-gloss alkyd, FR-63 (832-10814)	P1	Zinc phosphate alkyd primer
T2	Commercial gloss acrylic	P2	Red PVDC primer
T3	Experimental PVDC	P3	Epoxy polyamide primer
T4	Two-pack epoxy polyester		

Table 2: Experimental Paint Systems Trialled

No.	Primer	Topcoat
1	Alkyd primer	-
2	Alkyd primer	Alkyd topcoat
3	PVDC	-
4	PVDC	PVDC
5	PVDC	Acrylic latex
6	Alkyd primer	Epoxy polyester
7	-	Epoxy polyester
8		Epoxy polyester + 17% hydrated alumina
9	-	Epoxy polyester + 32% hydrated alumina
10	Epoxy polyamide	-
11	Epoxy polyamide (+ 17% hydrated alumina)	-
12	Epoxy polyamide (+ 25% hydrated alumina)	-
13	Epoxy polyamide (+ 32% hydrated alumina)	-
14	Acrylic latex	-
15	Epoxy polyamide	PVDC

2.1.2 Primers

The three primers examined in this study were chosen for the following reasons:

(i) **Zinc phosphate alkyd primer** (Table 1; No. P1). This primer is currently employed on RAN ships under the alkyd topcoat.

(ii) **PVDC primer** (Table 1; No. P2). A commercially available PVDC primer was used under a number of the PVDC topcoated panels and under all of the acrylic topcoated panels. This primer was selected because of the low water permeability of the PVDC resin which renders paint formulations suitable for use on steel substrates (see Table 6).

(iii) **Zinc phosphate epoxy polyamide primer** (Table 1; No. P3). This primer is widely used on RAN ships. The epoxy polyamide primer was employed under some of the PVDC and epoxy polyester topcoated panels.

2.1.3 Paint Schemes

The various paint schemes listed in Table 2 were applied to mild steel panels and examined for fire retardant properties by the procedures listed in 2.3. However, for LOI measurements, the paints were applied to glass cloth.

2.2 Painting Procedure

Steel panels were prepared for painting by degreasing in a trichlorethylene vapour bath followed by sanding or sandblasting. Paints were applied to steel panels or glass cloth using a conventional air spray gun operating at 270 kPa. Paint systems examined by reverse panel heating [3] were sprayed at a range of thicknesses between 25-575 µm. Systems evaluated by early fire hazard properties [1] were applied at thickness between 150-280 µm while coatings examined by the 2-foot tunnel test [2] were applied at thicknesses between 140-160 µm. Coatings applied to the glass cloth for LOI measurements [4] were sprayed on in two coats at a total thickness of 50-75 µm.

2.3 Resistance of Paints to Combustion

2.3.1 Evaluation of Fire Retardancy by Reverse Panel Heating

The fire retardancy of the paints by reverse panel heating was determined in accordance with AS K179-1969 [3] by impinging a flame from a gas burner to the reverse surface of a painted panel.

Each topcoat was assessed at a range of coating thicknesses to determine the effect of frequent repainting on the fire retardant performance. This follows from a US Navy report [5] that high film thicknesses pose increasing fire problems.

2.3.2 *Limiting Oxygen Index (LOI)*

The LOI method (AS 2122.2-1978 and ASTM D2863-74) [4], which determines the relative flammability of materials by measuring the minimum percentage oxygen concentration that will just support combustion yields reproducible and accurate numerical ratings for a variety of materials. The index was determined using a Stanton Redcroft Flammability Index Tester [9]. The paints were evaluated by coating both sides of a glass cloth with two coats of paint and air drying for 14 days. The glass cloth was cut into specimens 15 cm long and 5 cm wide.

2.3.3 *Assessment of Early Fire Hazard Properties of Materials*

The Australian Standard for Early Fire Hazard Properties of Materials (AS 1530.3-1982) [1] details a method for the assessment of surface finishes so that they may be classified according to:

(a) **The ignitability index**; this relates to the time taken for the volatiles from the specimens, irradiated at increasing intensity, to form an ignitable gas mixture resulting in a flame. The index number for ignition is defined as 20 minus the time of ignition in minutes.

(b) **The spread of flame index**; this relates to the rate of heat release by a burning material under applied radiation. The scale of the index is based on studies of actual rates of spread of flame on various wall lining materials. An index of 10 indicates that the material could be expected to cause flames to reach the ceiling within 10 s of ignition whereas an index of zero means that the material will not cause flames to reach the ceiling within 270 s of ignition. The index is linear between 0 to 8.

(c) **The heat evolved index**; this relates to the amount of heat released by a burning material. The index numbers form a linear scale which allows distinctions to be made between materials on the likelihood that the heat evolved would be likely to cause ignition of nearby combustibles. In the present instance, the extremely thin layer of combustible paint material is such that this value will be very small.

(d) **The smoke developed index**; this relates to the optical density of the smoke produced under the conditions of the standard examination.

AS 1530.8-1982 (AS) closely parallels ASTM E162-67 (ASTM) "Surface Flammability of Materials using a Radiant Heat Energy Source" employed by the US Navy in that both methods expose painted panels to gas-fired radiant heat sources and measure combustion characteristics and smoke production. (The US Navy employ ASTM E162 as part of DOD-C-24596 [10]). The AS and the ASTM procedures differ in several aspects, the major ones being sample dimensions, test position and assessment criteria. Whereas the AS employs a movable specimen mounted parallel to the radiant panel, the ASTM procedure

uses a fixed position for the test panel angled 30° to the radiation source. The AS procedure requires a 600 mm × 450 mm specimen moved towards a 300 mm square radiant panel in steps beginning at 850 mm and reducing to 175 mm over a 20 min period or until ignition occurs. The ASTM procedure requires that a 150 × 457 mm sample, angled at 30° towards a 300 mm × 457 mm radiant panel with the top of the sample 120 mm from the radiation source, be exposed until the flame front has progressed the full length of the specimen, or after an exposure time of 15 min. The intensity of the radiation in AS 1530.3 is adjusted to 2.4 kW/mm^2 by a radiometer 850 mm from the panel whereas ASTM E-162 requires that the radiant panel be operated at 816°C. The temperature of the AS 1530.3 radiant panel is approximately 900°C and the temperature of the test panels approximately 200°C at commencement and 450°C at the end of exposure.

2.3.4 *Direct Flame Impingement (2-Foot Tunnel Test)*

The Monsanto 2-foot tunnel test [2] was developed to correlate with the expensive 25-foot tunnel test. The tunnel consists of 24-inch × 4-inch (60 cm × 10 cm) piece of angle iron with a central channel 2.5 inches wide. The angle iron, which is inclined 28° from the horizontal, is boxed underneath. The painted specimen is placed coated side down on the angle iron over a burner and exposed to the flame for 5 min during which flame spread is measured. Insulation value, degree of intumescence, char volume and afterglow can be measured.

2.4 *Scrub Resistance*

Scrub resistance was carried out to determine the relative resistance of the paints to erosion when repeatedly scrubbed. This resistance is determined with a view to RAN ship housekeeping practices. The evaluations were carried out on single coats of paint applied to sandblasted glass plates.

The evaluations were based on United States Federal Test Method 141A No. 6142 [11] modified as follows:

(i) a 5% aqueous "Comprox" (Shell Chemicals Australia Pty Ltd) solution was employed instead of the Ivory flake solution as this detergent is currently used by the RAN.

(ii) the weight of the brush/brush holder was increased from the specified 450 g to 900 g to increase the severity of the test. Preliminary testing with the 450 g weight had minimal effect on the coatings under test.

2.5 Salt Spray Resistance

Salt spray resistance was carried out in accordance with ASTM B117-73 to compare each paint system with the alkyd standard for performance under a corrosive environment [12].

2.6 Washability

Washability evaluations were performed on (i) the alkyd topcoat, (ii) the acrylic topcoat and (iii) the PVDC topcoat.

The assessment was based on a procedure previously developed by MRL for Garden Island Naval Dockyard to evaluate the cleaning effect of a series of germicidal detergents on a non-slip coating used on the interior floors of ships. The soiling medium used was the same as that used on the non-slip coatings, namely

Raw umber	35 gram
White petroleum jelly	2 gram
Peanut oil	6 gram
Mineral spirits	29 gram

The soiling medium was applied to the test paints and excess medium was removed by scraping with the edge of a knife blade so that a minimum thickness of medium remained. The panels were dried for 4 h before cleaning the soiled paint areas with a 5% "Comprox" solution until no further soiling medium was removed by continued wiping of the panel.

The degree of discoloration remaining on the panel was determined by the measurement of residual colour on a Labscan spectrocolorimeter [13] employing an 8°/0° diffuse D65 light source with a 10° geometry observer excluding the spectral reflectance component. The CIELAB 1978 color system [14] was used and residual red pigment determined by difference in the value of the a* coordinate.

3. Results

3.1 Resistance of Paints to Combustion

The relative resistance of the paint systems when examined by the four techniques, namely reverse panel heating, LOI, radiant heating and direct flame exposure is discussed below.

3.1.1 Evaluation of Fire Retardancy by Reverse Panel Heating

Details of results, observations and times at which events took place for these examinations are given in Appendix 1. These may be summarized as follows:

(i) Alkyd (Reference System)

The alkyd paint schemes (alkyd primer and alkyd primer/alkyd topcoat) blistered and evolved a small amount of smoke. These schemes performed better than the epoxy polyester and the epoxy polyamide primer (including those with fire retardant additive), similar to the epoxy primer/PVDC topcoat system but worse than either the epoxy primer/PVDC topcoat system or the PVDC primer/acrylic topcoat system.

(ii) PVDC Coating

The PVDC primer and PVDC primer/PVDC topcoat behaved in a similar manner to the alkyd primer in that the material blackened and evolved a small amount of smoke.

(iii) Gloss Acrylic Latex

The gloss acrylic latex paint, which was applied over the PVDC primer produced very light smoke having a sweet odour characteristic of the acrylic monomer. No blackening of the coating was evident. Of those tested, this coating system performed best. However, when the acrylic latex was applied directly on to the steel panel without the chlorinated acrylic primer, the system blistered and caught fire after 32 s exposure.

(iv) Epoxy Polyamide

The epoxy polyamide primer blistered and produced a great deal of dense black smoke. The epoxy polyamide with hydrated alumina showed no apparent improvement in fire retardancy at each loading or coating thickness. Smoke production was reduced with the epoxy polyamide primer/PVDC topcoat system presumably as a result of the reduced exposure of primer to air.

(v) Epoxy Polyester

The epoxy polyester both with and without alkyd primer blistered, charred and produced copious amounts of thick black smoke. Epoxy polyester paint with hydrated alumina greatly reduced smoke production and charring at both 17% and 32% loading.

3.1.2 Limiting Oxygen Indices

Following the excellent performance of the water based coatings by reverse panel heating, the LOI's for the acrylic and PVDC based coatings were

compared with that for the RAN alkyd paint. The values are shown in Table 3. With LOI's of 32.1%, 289.% and 23.1% respectively, the PVDC, alkyd and epoxy polyester are self extinguishing while, as might be expected, the acrylic at 20.2% continued to burn on completion of the LOI examination.

Table 3: Limiting Oxygen Indices of Paints

Paint	LOI (%)
Acrylic	20.2
PVDC	32.1
Alkyd	28.9
Epoxy polyester	23.1

3.1.3 Early Fire Hazard Properties

The results of this test are shown in Table 4. The ignitability index for the coating systems showed that the paint based on PVDC was the only paint to resist combustion for the full exposure period of 20 min. Under increasing radiation intensity, the acrylic, alkyd and epoxy polyester paints all ignited in similarly sh t periods of time. These results are in agreement with those from the 2-foot [illegible] test.

Table 4: Early Fire Hazard Guidance Test

Samples	Epoxy Polyester	PVDC	Alkyd	Acrylic
Ignitability Index	15.5	0	17	17
Spread of Flame Index	0	0	9.5	0
Heat Evolved Index	0	0	1	0.5
Smoke Evolved Index	5	1	4.5	3

The low values for the heat evolved index reflect the low amounts of organic material contained within the coatings. The coatings were generally thin being 0.25 ± 0.02 mm (10 ± 2 mil) except for the epoxy polyester which was 0.17 mm (6.5 mil). In the case of the alkyd paint, the spread of flame index of 9.5 and the heat evolved index of 1.0 indicate a rapid shortlived spread of surface combustion due to the limited amount of organics present. These factors lead to a low value for the heat evolved.

The high value for the smoke produced index from the epoxy coating is in agreement with observations made during reverse panel heating and LOI tests.

3.1.4 2-Foot Tunnel Test

The flame spread was highest for the alkyd paint, followed by the epoxy polyester paint and the acrylic paint while the PVDC paint did not burn in the 2-foot tunnel test (Table 5). Although the acrylic and epoxy polyester have similar flame spreads, the periods of combustion are significantly different: the acrylic paint burnt briefly for approximately 20 s, whereas the epoxy polyester paint continue to burn for around 200 s.

Table 5: Flame Spread: Monsanto 2-Foot Tunnel Test

Time (s)	Coating			
	Epoxy Polyester	Acrylic	Alkyd	PVDC
15	-	-	7	-
30	7	-	14	-
45	7	-	12	-
60	8	5	6	-
75	8	7	6	-
90	8	-	-	-
105	8	-	-	-
120	8	-	-	-
135	8	-	-	-
150	9	-	-	-
165	9.5	-	-	-
180	8	-	-	-
195	8	-	-	-
210	7	-	-	-

3.2 Application Properties

Paint systems employing the alkyd and epoxy primers showed good application properties. The PVDC primer, however, showed a tendency to rust if the primer thickness was less than 75 µm. Attempts at using acrylic gloss latex paint over a single coat of PVDC primer resulted in areas of flash rusting appearing on the white acrylic topcoat. The red iron oxide pigmented PVDC primer disguises the presence of flash rusting when primer is applied. The flash rusting persisted through multiple coats of the acrylic paint over a single PVDC primer coat and led to the requirement for two coats of PVDC primer

when using these acrylic gloss topcoats. The persistence of flash rusting with the acrylics is presumably due to the greater water adsorption and diffusion typical of these latices (Table 6). This effect occured to a lesser degree when a single PVDC topcoat was applied over a single coat of PVDC primer.

Table 6: Water Adsorption and Diffusion of Latex Paints [11]

Paint	Water Adsorption (%)	Water Vapor Diffusion (g/m^2 d)
Acrylic	27	86
Styrene acrylic	4	11
PVDC	1	0.5

3.3 Gloss

Visual gloss levels (AS K179) of the paint systems were evaluated at 60° and are shown in Table 7.

Table 7: Gloss Levels of Test Paints

Paint	Gloss Level
Alkyd semi-gloss enamel	35
Acrylic gloss	70
PVDC topcoat	60
Epoxy polyester	90
Epoxy polyamide primer	90

3.4 Scrub Resistance

An upper limit for the number of scrubbing cycles was set at 10 000. Such a limit is in excess of actual performance requirements but would more clearly determine the superior coating.

3.4.1 Alkyd System

The alkyd system proved to be of high scrub resistance, exceeding 10 000 cycles without significant deterioration of the coating. The only visible sign of damage was a slightly worn path from the scrubbing brush which appeared as an opaque streak on the surface of the coating.

3.4.2 Acrylic Topcoat

The test was halted at between 5 000 and 6 000 cycles due to the partial disbonding of the leading edge of the paint film from the glass panel.

Although this problem occurred after 5 000 cycles, the coating is regarded as having performed well as there was only slight scuffing of the scrub path.

3.4.3 PVDC Topcoat

The PVDC topcoat performed better than the acrylic topcoat in the scrub resistance test. The adhesion problem observed for the acrylic was not a significant problem for the PVDC coating. Although partial disbonding was noted for one panel (7 000 cycles), a second panel went the full 10 000 cycles without failure. This indicates that the PVDC topcoat had a higher resistance to the detergent solution than the acrylic.

Thus, the relative scrub resistance of the three paints tested is as follows:

alkyd > PVDC > acrylic

3.5 Salt Spray Resistance

The PVDC/acrylic paint scheme formed small pinhead blisters which increased in size over the 1 000 h of the test. Approximately 5% of the panel blistered. The alkyd paint scheme, the epoxy primer/PVDC topcoat and the PVDC primer/PVDC topcoat passed 1 000 h salt spray resistance.

3.6 Washability

The results of the washability of the four paint systems, namely (i) the alkyd primer/alkyd topcoat presently used by the RAN, (ii) PVDC primer/acrylic latex, (iii) PVDC primer/PVDC topcoat and (iv) epoxy primer/PVDC topcoat were as follows:

(i)	the residual pigmentation on the alkyd:	1.08
(ii)	the residual pigmentation on the acrylic:	8.69
(iii)	the residual pigmentation on the PVDC:	3.50
(iv)	the residual pigmentation on the PVDC/epoxy:	3.25

4. *Discussion*

The different procedures for evaluation of fire retardance showed that the alkyd paint presently used by the RAN for interior areas of ships successfully passed the reverse panel heating test, yet displayed poor resistance to ignition and had the highest rate of flame spread of the coatings by both radiant exposure and direct flame impingement tests. The apparent difference in fire retardance as determined by these procedures is of concern. The manner in which the alkyd paint passes the reverse panel heating test is by forming a large blister under the coating and physically separating the paint film from the substrate, presumably by the formation of volatile compounds. This physical separation of substrate and paint raises questions about the resistance of the coating in a shipboard fire.

The high spread of flame index for the alkyd paint was in agreement with observations by Gracik and Morris [6] who found that a solvent based unretarded alkyd paint showed a lower threshold film thickness (for flaming) than all other paint systems when evaluated by a radiant heating procedure. Even at the lowest film thickness evaluated (200 to 225 µm) they reported that the alkyd paint system flashed into a violent ball of flames which extended to the roof of the test chamber. The high level of surface flammability of the alkyd paints presumably reflects the high calorific values of the long oil resins in these paints. The general effect of raising heat flux and thus temperature, is to reduce the fire resistance or retardance of a material. The results suggest that in a fire, ignition of the alkyd paint would be followed by rapid spread of flames across painted areas as occurred on HMAS Sheffield [7] when destroyed by a missile attack during the Falklands War.

The high ignitability index of the acrylic and epoxy paints, like that of the alkyd paint, suggests that they would be similarly susceptible to ignition from adjacent fires.

The resistance to combustion of the PVDC paints in both the early fire hazard properties and 2-foot tunnel evaluations make paint systems with PVDC resins attractive where fire retardancy is required. The tendency of the PVDC primers to exhibit flash corrosion at thicknesses less than 75 µm raises concerns regarding PVDC primer application properties. However the use of an epoxy primer with a PVDC topcoat was found to overcome application problems while exhibiting good maintenance and fire retardant properties.

The water based paints performed better than the other systems in a number of the procedures. In the reverse panel heating test, the acrylic topcoat over PVDC primer was the most effective paint system with little smoke generation and no charring. However, this is believed to be due to the fire retardance of the PVDC primer. Further testing of acrylic primer/topcoat showed that the acrylic system failed the test badly, bursting into flames half-way through the exposure period. This result is in agreement with the LOI performance.

The evaluation of flammability of the topcoats by LOI indicated that the PVDC based coating was the most resistant. The acrylic gloss paint was capable of combustion at an oxygen concentration below atmospheric levels and at the termination of the evaluation procedure, the acrylic paint continued to burn on removal from the equipment as might be expected from the low LOI value.

The resistance to combustion of both the epoxy polyester and untopcoated epoxy polyamide primer, as determined by the reverse panel heating test (Appendix 1), was lower than that of the water-borne systems employing the PVDC primer. Excessive generation of smoke by the epoxy paints during this test was noted. This is in close agreement with the smoke levels reported by the early fire hazard properties (Table 4). The use of a water based topcoat over a solvent-borne epoxy polyamide primer reduced smoke production. The use of hydrated alumina, which is widely used to improve fire retardancy was of only minor advantage in the epoxy systems. There was no discernible improvement in the fire retardant properties of the epoxy polyamide primer with hydrated alumina and only slight improvement in the epoxy polyester. Even so, the performance was still well below that of the water-borne paint systems assessed without fire retardant additives. The smoke from each of the epoxy coatings was irritating, acrid and excessively dense. Smoke generation was therefore considered to be the greatest problem associated with burning of these coatings.

The part played by paint in shipboard fires in earlier conflicts is well recorded [5] particularly in World War II. As a result of this information, paints were developed which were fire retardant by virtue of their high pigment loading. Since that time, other fire retardant resins have been developed and adopted by navies. However, the effectiveness of these newer paints against fires on naval ships involved in recent military conflicts has been difficult to assess in view of the involvement of other materials and the general lack of information on public record. Generally, the chlorinated resins used by USN are reported to have assisted in suppression of fire spread. The contribution to fire of the high pigment loaded alkyd paints used by the Royal Navy is less well recognized at this time.

The nature of the combustion products of the various coating schemes is a subject that requires further investigation. While the use of chlorinated resins may retard combustion, their use presumably gives rise to hydrogen chloride in the combustion products. The release of solvents from newly applied paint systems is also of concern on health and safety grounds, particularly release into enclosed areas, which likewise requires further examination.

During discussions at the 8th Internaval Corrosion Conference, Kaznoff [15] suggested that analysis of experience in the Persian Gulf indicated that the use of fire retardant paints on the interior areas of US ships "did quite well". At this time, Allison [16] reported that UK shipboard fires did not indicate a significant contribution from paint to the fire damage. However, he suggested that tests carried out by British authorities showed that UK fire retardant paints would not pass requirements when 6 coats of paint were present. He made the comment that up to 90 coats had been found inside ships. Discussions with US authorities [17] at the ABCA-8 conference following the Stark incident confirmed that the use of paints based on chlorinated resins had assisted in preventing fire spread. Preston [7] reported that the heat from the plating of the steel decks on HMS Sheffield was conducted down the hull starting fires elsewhere.

The above observations raise questions about the significance of the fire evaluation procedure specified by British and RAN regulations. The reverse panel heating test required for fire resistant interior shipboard paints reputedly identifies these paints which resist fire passage through a ship resulting from

heat transfer through the bulkhead igniting the paint in adjacent compartments. In this test, a small heat source which is applied for 1 min to the back of a painted steel panel, caused the formation of a single large blister. The paint passes the test because of the physical separation of paint and panel rather than inherent fire resistance of the paint film. However, blister formation which physically removes paint from a point heat source may or may not occur with widespread heating on the reverse side of a bulkhead.

In the present investigation, the maintenance properties of the coatings have also been examined with regard to shipboard use. The gloss characteristics of the coatings show considerable variation. The recommended gloss levels for AS K179-1969 (Semi-Gloss Enamel) are between 30 and 40. The use of the epoxy polyester on surface ships (gloss 90) by painters and ship personnel has apparently occurred because Navy personnel prefer the high gloss of this paint regardless of recommended levels.

The performance of both the PVDC and acrylic coatings with respect to scrub resistance is considered to be acceptable for Navy requirements. However, the PVDC primer/acrylic topcoat paint formed small pinhead blisters after 150 h which increased in size during the 1000 h evaluation and is considered unsatisfactory. On the other hand, the alkyd, epoxy primer/PVDC topcoat and PVDC primer/PVDC topcoat systems all passed 1000 h salt spray resistance.

The washability of the systems which had performed well in the fire testing were evaluated, namely the alkyd primer/alkyd paint, the PVDC primer/acrylic gloss latex, the epoxy polyamide primer/PVDC topcoat and the PVDC primer/PVDC topcoat. The washability testing indicated that the alkyd system was easily the best coating and the PVDC/acrylic the worst. Residual pigmentation on the alkyd was only about a third of that remaining on the PVDC systems and one eighth of that on the acrylic gloss topcoat. Reports [18] from Garden Island Dockyard suggest that an earlier shipboard trial with a gloss acrylic latex paint was terminated following the poor washability performance of the coating. In view of the intermediate performance of the PVDC coating, washability performance "in Service" may be critical to its widespread acceptance.

5. *Conclusions*

(i) Water based latex paint systems for use on the interior areas of RAN ships were evaluated for fire retardant and maintenance properties. Paint schemes based on an epoxy polyamide primer and PVDC topcoat exhibited excellent maintenance and fire retardant properties.

(ii) All paint systems except those with PVDC topcoats were ignited by the radiant heating procedure. Similar results were obtained by direct flame impingement examination.

(iii) The fire resistant alkyd paint presently used in RAN ships exhibited high values for spread of flame index by direct flame impingement and radiant heating. The alkyd paint also had a high ignitability index.

(iv) Acrylic paints were found by LOI to burn at atmospheric oxygen levels. Other systems examined were self extinguishing under atmospheric conditions.

(v) The epoxy polyester paints blistered, charred and produced excessive amounts of a choking black smoke under all examination conditions.

(vi) The variation between results obtained from paints when examined by AS K41 and those by radiant heating and direct flame impingement reflects different properties of the paints. Examination has shown that AS K41 measures the fire retardant properties of the undercoat whereas the other two reflect the retardant properties of the topcoat.

(vii) The overall results of maintenance and fire retardant examinations strongly suggest that the paint system based on a zinc phosphate epoxy polyamide primer and a PVDC topcoat would greatly improve fire retardancy while providing excellent maintenance properties. The use of this water based topcoat would overcome the requirement for solvents on ships for topcoat paint repairs.

6. *References*

1. Early fire hazard guidance test. Australian Standard 1530.3-1982. *Methods for fire test on building materials and structures.* Standards Association of Australia.

2. Vandersall, H.L. (1967). Small scale evaluation of fire-retardant paints by 2-foot method. ASTM D3806. The use of a small flame tunnel for evaluating fire hazard. *Journal of Paint Technology*, 39 (511), 494.

3. Semi-gloss enamel – Low fire hazard for noncombustible surfaces (primarily for Service use). Australian Standard K179-1969. *Methods of test for paints, varnishes, lacquers and related materials.* Standards Association of Australia.

4. Method for measuring the minimum oxygen concentration to support candle-like combustion of plastics. ASTM D2863-74. *Determination of minimum oxygen concentration for flame properties following top surface ignition of vertically oriented specimens.* Australian Standard 2122.2-1978. Standards Association of Australia.

5. Grubb, R. and Cranmer, W.W. (1954). Testing fire-retardant paints under simulated service conditions. Fire retardant paints. *Adv. in Chem.*, Series 9, ACS, Los Angeles, 48-66.

6. Gracik, T.D. and Morris, J.G. (1987). *Correlations between thickness of shipboard navy interior paints and small scale fire tests* (SME 86/80). David Taylor Research Center.

7. Preston, A. (1982).
Sea combat off the Falklands. The lessons that must be learned. Willow Books.

8. Furgeson, C. (1986).
Personal communication. HM New Zealand Dockyard, Auckland.

9. Stanton Redcroft FTA flammability index tester. Ser. No. 710. Stanton Redcroft Ltd, London SW17.

10. US Department of Defense Specification DOD-C-24596, *Coating compounds, nonflaming, fire-protective.*

11. Federal Test Method Std. No. 141A, Sect. 6000. *Physical and chemical test for dried films. Scrub resistance.* Method No. 6142, Sept. 1 (1965).

12. ASTM B-117-73. *Standard method of salt spray (fog) testing.*

13. Hunter Labscan II sphere spectrocolorimeter. Hunter Associates Laboratory, Inc. Reston Va. 1984.

14. Recommendations on uniform color spaces, color difference equations, psychometric color terms. Supplement No. 2, CIE Publications No. 15 (E-1.3.1), CIE Paris 1978.

15. Kaznoff, A.I. (1988).
8th Internaval Corrosion Conference. Director, Materials Engineering and Assurance Office, NAVSEA, Washington, DC.

16. Allison, D.M. (1988).
8th Internaval Corrosion Conference.

Appendix 1

Reverse Panel Heating Performance of Paint Systems (AS K179-1969)

Paint Type	Test Number	Number of Coats	Thickness (µm) (average)	Time to Blister (s)	Time to Smoke (s)	Time to Breakage (s)	Time to Spark (s)	Detachment (s)	After Glow
Phosphate alkyd primer	1	1	53	Nil	20	Nil	Nil	Nil	No
Alkyd primer & topcoat	2	1 Primer 1 Top	71	8	13	40	48	Nil	No
	3	1 Top	81	9	15	47	53	Nil	No
	4	2 Top	127	8	30	49	Nil	Nil	Yes
	5	2 Top	127	7	27	60	Nil	Nil	No
	6	4 Top	198	7	20	Nil	Nil	Nil	No
	7	4 Top	178	7	25	60	Nil	Nil	No
	8	6 Top	254	7	19	50	60	Nil	Yes
	9	6 Top	254	7	21	60	60	60+	Yes
	10	8 Top	318	7	38	Nil	Nil	Nil	No
	11	8 Top	343	7	43	Nil	Nil	Nil	No
Alkyd primer Epoxy polyester topcoat	12	1 Primer 1 Top	109	11	48	Nil	Nil	Nil	No
	14	1 Top	112	10	43	Nil	Nil	Nil	No
	15	4 Top	292	9	30[a]	Nil	Nil	Nil	No
	16	4 Top	292	8	30[a]	Nil	Nil	Nil	No
	17	8 Top	584	10	35[b]	Nil	Nil	Nil	No
	18	8 Top	559	9	33[b]	Nil	Nil	Nil	No
Epoxy polyester (no primer)	19	2	117	20	18	35*/40**	Nil	Nil	No
	20	2	109	10	19	35*/38**	Nil	Nil	No
	21	4	203	10	18	32*/50[c]	Nil	Nil	No
	22	4	208	10	19	42*/50[c]	Nil	Nil	No
	23	6	343	13	23	15[d]	Nil	Nil	No
	24	6	330	11	33	40[e]	Nil	Nil	No
	25	8	533	12	18	13	Nil	Nil	No
	26	8	559	10	18	10	Nil	Nil	No
PVDC primer & acrylic topcoat	27	1 Primer	33	-	12	Nil	Nil	Nil	No
	28	1 Primer	36	-	10	Nil	Nil	Nil	No
	29	1 Primer 1 Top	114	6	22	[f]	Nil	Nil	No
	30	1 Primer 1 Top	122	6	21	Nil	Nil	Nil	No
	31	2 Top	127	7	22	Nil	Nil	Nil	No
	32	2 Top	162	7	21	Nil	Nil	Nil	No
	33	4 Top	229	6	23	Nil	Nil	Nil	No
	34	4 Top	267	6	22	Nil	Nil	Nil	No
	35	6 Top	330	6	35	Nil	Nil	Nil	No
	36	6 Top	330	6	38	Nil	Nil	Nil	No
	37	8 Top	508	7	25	Nil	Nil	Nil	No
	38	8 Top	483	7	23	Nil	Nil	Nil	No
PVDC primer & topcoat	39	1 Primer 1 Top	71	6	13	23	Nil	42	No
	40	3 Top	208	7	33	[f]	Nil	Nil	No
	41	6 Top	406	7	45	[f]	Nil	Nil	No

Paint Type	Test Number	Number of Coats	Thickness (µm) (average)	Time to Blister (s)	Time to Smoke (s)	Time to Breakage (s)	Time to Spark (s)	Detachment (s)	After Glow
Epoxy polyester 17% hydrated alumina	A	1	97	13	23	50	Nil	42[g]	No
	B	3	279	10	19	Nil	Nil	Nil	No
	C	6	508	11	35	Nil	Nil	Nil	No
Epoxy polyester 32% hydrated alumina	D	1	97	16	18	Nil	Nil	Nil	No
	E	3	254	11	25	Nil	Nil	Nil	No
	F	6	559	11	26	Nil	Nil	Nil	No
Epoxy polyamide	G	1	69	27	19	[h]	Nil	Nil	No
	H	3	229	7	20	25	[i]	Nil	No
	I	6	533	7	50	51	[j]	Nil	No
Epoxy polyamide 25% hydrated alumina	J	1	79	17	20	26[k]	Nil	Nil	No
	K	3	249	7	30	30[l]	Nil	Nil	No
	L	6	432	6	60	60[m]	Nil	Nil	No
Epoxy polyamide 17% hydrated alumina	M	1	76	18	18	23[n]	Nil	Nil	No
	N	3	152	7	21	22[o]	Nil	Nil	No
	O	6	432	7	17	17[p]	Nil	Nil	No
Epoxy polyamide 32% hydrated alumina	P	1	56	-	25	[q]	Nil	Nil	No
	Q	3	173	15	23	[r]	Nil	Nil	No
	R	6	559	7	28	43[s]	Nil	Nil	No
Acrylic	S	2		14	25	32[t]	Nil	Nil	No
Epoxy primer PVDC topcoat	T	1 Primer 2 Top	125	13	22	40[u]	Nil	Nil	No

* Pinhole
** Break. Heavy smoke
a Pinholes spewing out dense smoke
b Smoke not as dense as above
c Break. Heavy smoke
d Heavy black smoke @ 54 s
e Heavy black smoke @ 45 s
f Very light smoke
g Black smoke @ 59 s
h Tiny blisters. Heavy smoke
i Melt @ 30 s. Heavy smoke
j Melt @ 57 s. Heavy smoke
k Pin holes. Heavy smoke @ 37 s
l Pin holes. Melt @ 47 s. Heavy smoke
m Melt/Heavy smoke
n Pin holes. Melt @ 35 s. Heavy smoke
o Pin holes. Melt @ 31 s. Heavy smoke
p Pin holes. Melt @ 44 s
q Heavy smoke
r Melt @ 42 s
s Pin holes. Melt @ 57 s. Heavy smoke
t Vigorous combustion
u Pinholes. Moderate smoke

DOCUMENT CONTROL DATA SHEET

REPORT NO.	AR NO.	REPORT SECURITY CLASSIFICATION
MRL-TR-91-31	AR-006-821	Unclassified

TITLE

Fire retardant performance of interior shipboard paint schemes by different techniques

AUTHOR(S)
L.V. Wake

CORPORATE AUTHOR
Materials Research Laboratory
PO Box 50
Ascot Vale Victoria 3032

REPORT DATE	TASK NO.	SPONSOR
September, 1991	NAV 88/125	RAN
FILE NO.	**REFERENCES**	**PAGES**
G6/4/8-4073	18	26

CLASSIFICATION/LIMITATION REVIEW DATE

CLASSIFICATION/RELEASE AUTHORITY
Chief, Protective Chemistry Division

SECONDARY DISTRIBUTION

Approved for public release

ANNOUNCEMENT

Announcement of this report is unlimited

KEYWORDS

Paints	Coatings	Vinylidene Chloride Resins
Water based paints		

ABSTRACT

The fire retardant performance of alternative paints to the alkyd paint system presently protecting the interior areas of Royal Australian Navy (RAN) ships has been evaluated. Topcoats investigated were: (i) a polyvinylidene chloride (PVDC) latex paint; (ii) an acrylic latex paint; (iii) an epoxy polyester paint, and (iv) the RAN alkyd paint. The paints were examined in a number of primer/topcoat systems by combustion under limiting oxygen index (LOI), radiant heat exposure, direct flame exposure and reverse panel heating. Some rating variation between procedures was observed although the latex based PVDC topcoat had the highest rating by all test methods. The variability was exemplified by the present RAN fire retardant alkyd paint which successfully passed the reverse panel heating test, had a self-extinguishing LOI of 28.9%, yet had a high flame spread by radiant heating and direct flame exposure. A paint scheme comprising an epoxy polyamide primer and a PVDC topcoat exhibited excellent fire retardant and maintenance properties and should be considered by RAN for a trial to determine in-Service shipboard performance.